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SUPERCONDUCTIVE GATING DEVICES

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9 Claims. (Cl. 307—88.5)

This invention relates to electrical devices, and particularly to those devices employing superconductors.

This application is a continuation of Serial No. 680,456, filed August 27, 1957, now abandoned.

The properties and characteristics of superconductors have been treated in such texts as "Superfluids," volume I, by Fritz London, published in 1950 in New York by John Wiley & Sons, Inc., and "Superconductivity" by D. Shoenberg, published in 1952 in London by the Cambridge University Press. In general, a superconductor is a metal, an alloy or a compound that is maintained at very low temperatures, i.e., from 17° K. to the practical attainability of absolute zero, in order that it may present no resistance to current flow therein. It was discovered that in the case of mercury its electrical resistance decreased as a function of decreasing temperature until at a given temperature (about 4.12° K.) the resistance very sharply vanished, or its measurement was too small to be detected. The temperature at which the transition to zero resistance took place in mercury was referred to as its critical temperature; its state, upon reaching zero resistance, was that of a superconductor.

The critical temperature varies with different materials, and for each material it is lowered as the intensity of the magnetic field around the material is increased from zero. Once a body of material is rendered superconductive, it may be restored to the resistive or normal state by the application of a magnetic field of a given intensity to such material; the magnetic field necessary to destroy superconductivity is called the critical field. Thus it is seen that one may destroy superconductivity in a specific material by applying energy to it in the form of heat so as to reach its critical temperature, or in the form of a magnetic field so as to reach its critical field.

In a plot of the magnetic field as the ordinate versus temperature as the abscissa, wherein the magnetic field is the critical field in gauss and the temperature is in ° K., one obtains a series of curves for different materials. If at a selected temperature, i.e., 4° K., one draws a line at right angles to the abscissa, such constant temperature line will intersect various curves at different points. Such intersections will represent the magnetic fields that are necessary to drive their respective materials to their resistive states for the selected temperature of 4° K. At the temperature of 4° K. one material may require only fifty gauss to be driven from its superconductive state to its resistive state, a second may require 300 gauss, a third may require 450 gauss, etc. For purposes of aiding in the discussion to follow, a hard superconductor is defined as that superconductor which, at a given operating temperature, requires a relatively high field or current to cause it to go resistive or normal conducting, whereas a soft superconductor is defined as that which requires a relatively low field or low current to cause it to go normal. It was also recognized that a closed path or ring of superconducting material (see paragraph 2.6 of the above cited Shoenberg text) will act as a barrier to a magnetic field that is normal to the plane of such closed path or ring. When that magnetic field is increased to the point that it exceeds the critical field of the superconducting material, the latter goes resistive, permitting the penetration of the magnetic field through the ring. It was not known, however, that the change in resistance of the superconductor could be caused to create a heating effect which further increased the resistance of the superconductive ring. If the ring could be caused to increase its resistance as a result of this heating, the changed resistance of the superconductive ring would be effective to accelerate the field, which acceleration would also heat the ring by inductive heating. The aforementioned regenerative effect and its recognition are exploited herein to produce more effective superconductive elements and devices.

One special application of this discovery is toward the construction of a novel cell to be used in computers wherein the geometry of the cell is such as to inductively store energy during the interval when the superconductive closed path is being driven toward its resistive state. The cell is also capable of releasing such inductively stored energy so that the latter manifests itself as a heat generator or as a means for generating a rapidly changing magnetic field. This invention will deal with instrumentalities that will make use of the heating effect, per se, to cause a very rapid switching of the superconductive cell, per se, or to cause the rapid switching of other superconductor elements. Where it is desired to make use of the rapidly changing field, a suitable sensing device will be placed in the path of such rapidly changing magnetic field so as to transmit an amplified signal to a suitable utilization circuit.

Wherein it is desired to exploit the regenerative heating effect of a switching superconductor cell to achieve control of other superconductors, a hard superconductor is placed adjacent to and in heat-conducting relationship with a soft superconductor. The soft superconductor will require a relatively small critical magnetic field to make it go resistive and regeneratively heat up to give a rapid temperature rise, say of the order of

$$\frac{3\text{–}15^\circ \text{ K.}}{1\text{–}15 \text{ millimicroseconds}}$$

The heat energy is transmitted to the hard superconductor to raise its temperature so as to drive it resistive or normally conductive. Since the hard superconductor requires a relatively large critical field to drive it resistive, the use of a low critical field as a means for driving a soft superconductor into its resistive state so that the latter, when it regeneratively heats up, can switch a hard superconductor to its resistive state attains amplification. A relatively small current in a drive winding associated with a soft superconductor of the novel superconductive cell will cause the soft superconductor to go resistive and the heat regeneratively produced will control the state of a hard superconductor, the latter capable of carrying a relatively large current. Thus a small current change in a soft superconductor can be made to control the passage of a large current in a hard superconductor. It will also be shown hereinafter that a change in state of any superconductor, i.e., when the latter is made to switch from its superconductive state to its resistive state so as to produce a regenerative heating effect, can be made to control another superconductor regardless of the relative hardness or softness of the two superconductors.

Accordingly it is an object of this invention to provide a novel cell employing superconductive elements.

It is a further object to attain a superconductive cell capable of being switched very rapidly.

It is yet another object to provide a rapidly switching cell that is exceedingly small in size and mass so that its use in computers will serve to reduce the over-all size of such computers.

Still another object is to control the switching of a second superconductor by the heat regeneratively produced when a first superconductor is made to go resistive.

A further object is to employ a soft superconductor to